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MEMORANDUM FOR IN-HOUSE PUBLICATIONS

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SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-**TP**-1998-**085**
C.T. Liu and H. Ho "Damage Mechanisms and Crack Growth in a Particulate Composite Material"
EXTENDED ABSTRACT **(Statement A)**

Damage Mechanisms and Crack Growth in a Particulate Composite Material

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In recent years, fibrous composite materials have been widely used in aerospace and automobile industries due to their high modulus and strength to weight ratio. Particulate composites, though not as effective as the continuous fibrous composites in improving modulus and strength of the matrix materials, are also widely used in construction and commodity industries for their improved performance over the matrix material in, for example, thermal and electrical conductivities, friction and wear resistance, machinability, surface hardness, and cost effective. However, much of the studies about the particle reinforced polymeric composites are on the derivation of the effective elastic properties and the development of the constitutive models of the materials. In recent years, a considerable amount of work has been done in studying the crack growth behavior in highly filled polymeric materials. These materials consist of hard particles contained in a soft elastomeric binder. Experimental results indicate that power law relationships exist between the crack growth rate and the Mode I stress intensity factor which are consistent with the theories developed by Knauss and Schapery in their study of crack growth in viscoelastic materials.

It is well known that, on the microscopic scale, highly filled polymeric materials can be considered nonhomogeneous materials. When these materials are stretched, the different sizes and distribution of filler particles, the different crosslink density of polymeric chains, and the variation of the bond strength between the particles and the binder can produce highly nonhomogeneous local stress and deformation fields. Depending upon the magnitudes of the local stress and strength , damage can be developed in the material, especially near the crack tip. In the region near the crack tip where the material is highly stressed, microcracks or microvoids are developed. As the material is further stretched, the microvoids may coalesce and form a large void and promote the rapid growth of the main crack. Therefore, in order to obtain a fundamental understanding of crack growth behavior in the highly filled polymeric materials, a detailed knowledge of the characteristics of damage evolution, crack-defect interaction, and local fracture behavior near the crack tip is required.

In this study, the local strain fields and damage accumulation process near the crack tip in a particulate composite, containing hard particle embedded in a rubbery matrix, subjected to a constant strain rate were investigated using pre-cracked sheet specimens. The specimens were 20.32 cm. wide ,5.08 cm. long, and 0.51 cm. thick. A 3.81 cm. crack, which was parallel to the longest side of the specimen and perpendicular to the loading direction was cut at the center of the specimen. A coarse grid with 0.2 mm. spacing between the vertical and the

horizontal grid lines was deposited on the surface of the specimens. During the test, a camera was used to photograph the deformed grid near the crack tip at selected time intervals. The experimental data were processed to determine the strain fields near the crack tip and the crack growth behavior in the material. In addition, three-dimensional finite element analyses were performed to evaluate the effects of the interaction between the main and the secondary cracks on the Mode I stress intensity factor at the crack tip.

A typical set of photographs showing the crack surface profile and local damage during the opening and growth of a crack in the specimen is shown in Fig.1. Experimental findings reveal that crack tip blunting takes place both before and after the crack growth. Due to the heterogeneous nature of the highly filled polymeric material, the degree of blunting varies with the position of the advancing crack tip, and the crack growth consists of a blunt-growth-blunt phenomenon which appears to be highly nonlinear. This suggests that the local microstructure, or local damage, near the crack tip plays a significant role in the blunting phenomena. The local damage and the blunting at the crack tip will relax the local stress, resulting in a high resistance to propagation of the crack. The crack growth resistance decreases as the magnitude of the applied load and the degree of damage are increased. It is believed that the time-dependent of the damage and fracture mechanisms are contributing factors to the time-sensitivity and discontinuous crack growth behavior in highly filled polymeric materials. Experimental finding also reveal that the increase of the applied strain alters the strain fields but the iso-strain contours are of the same general form.

The results of the finite-element analysis show that, depending upon the size and the location of the secondary crack, the interaction of the main and the secondary cracks can increase or decrease the magnitude of the stress intensity factor at the crack tip. Since the crack behavior is controlled by the stress intensity factor, it is believed that the interaction between the main and the secondary cracks is a contributing factor for the fluctuation in crack growth rate observed experimentally.

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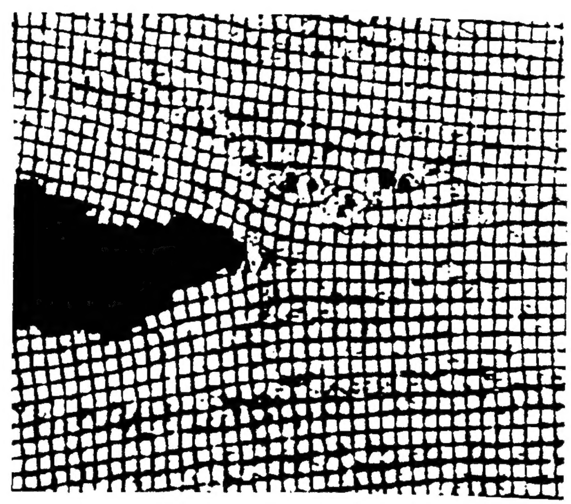

Fig. 1 Crack Tip Profile